

AIS SPORTS SUPPLEMENT FRAMEWORK

CARNITINE (L-CARNITINE)

What is it?

- > L-carnitine is derived from the amino acids lysine and methionine within the human body but can also be ingested from animal products. A deficiency of carnitine is rare, even in vegans. Carnitine is stored within the heart and skeletal muscles, and has several roles.
 - An obligatory component of the transfer process for fatty acids from the bloodstream into muscle mitochondria for use as fuel.
 - Buffers excess acetyl-CoA within the mitochondria in order to maintain the rate of fuel delivery from carbohydrate during prolonged endurance exercise and reduce lactate accumulation during high intensity exercise.
 - May play an anti-oxidant role to help muscle recovery and reduce muscle protein breakdown following intense exercise such as heavy training loads or repeated competition performance over short time periods.
- > For carnitine supplementation to change fatty acid transport and buffering capability within the muscle mitochondria, it would be necessary to increase muscle carnitine concentration. However, very few studies have measured muscle carnitine concentrations as this is technically challenging to do.
 - There is no evidence for changes in muscle carnitine concentrations following short periods (4 weeks or less) of supplementation, nor in most longer term studies which do not co-ingest carbohydrate with the carnitine.
 - Two longer term studies undertaken in recreational athletes (1.4-3g L-carnitine daily for 12-24 weeks) showed increases in muscle carnitine concentration were possible provided a sufficient amount of carbohydrate (80g) was consumed with each dose of L-carnitine.^{1,2} However, the metabolic and performance benefits remain uncertain, with one study showing an increased work output over 30 min all out performance test at 24 weeks supplementation (but no increase at 12 weeks¹) while Shannon et al.² found no impact on high intensity interval training adaptations.
 - A similar carnitine supplementation protocol (2g L-carnitine daily for 12 weeks) but without carbohydrate co-ingestion increased muscle carnitine concentration in vegetarians but not omnivores. No differences were found in energy metabolism or lactate levels during 1 hour of moderate intensity exercise in either group³ across the study.
 - Over the first 12 weeks of supplementation in the study by Wall et al.¹, body fat increased 1.8kg (perhaps as a result of an extra 160g carbohydrate per day) in the control group but did not change in the carnitine group. This may be partly explained by a higher energy expenditure during 30 min exercise at 50% $\dot{V}O_{2max}$ in the carnitine-supplemented group.⁴ However, since there were no body fat changes reported by Shannon et al.² using a similar supplementation protocol, it is difficult to know whether this was an impact of the carnitine supplementation or other factors over that extended period of time.
- > Preliminary research on muscle pain, muscle disruption (via MRI) and blood markers of muscle damage have found favourable adaptations following 3 weeks L-carnitine supplementation.⁵
- > One study of 9 weeks supplementation of 2g L-carnitine L-tartrate daily during resistance training found reductions in markers of oxidative stress and improvements in muscle strength but not muscle mass.⁶
- > Carnitine is also a popular weight loss supplement due to its proposed role in facilitating fat oxidation. However, there is a lack of evidence supporting the efficacy of carnitine in further enhancing fat loss.

Carnitine may be useful in several clinical settings where carnitine deficiency may be induced, such as maintaining brain and muscle function in the elderly and in the treatment of some forms of cardiovascular disease. Vegetarians may be particularly responsive to carnitine supplementation, presumably because of lower dietary intake.

What does it look like?

- > Carnitine is generally found in powdered form, which may be encapsulated to better enable ingestion of specific doses.
 - The most common variant used for athletes is L-carnitine L-tartrate.
 - There are also liquid forms of L-carnitine on the market, however this form of carnitine has generally not been researched and rarely achieves carnitine doses used in research studies.
 - Other forms of carnitine, such as acetyl-L-carnitine and propionyl-L-carnitine have been used in clinical settings only.

How and when do I use it?

- > In theory, athletes most likely to benefit from carnitine supplementation include endurance competition events (>30 mins duration), prolonged high intensity exercise (such as team sports), and aiding in recovery during heavy training loads or resistance exercise.
- > Recommended dose is 1.4-3g L-carnitine (2-4g L-carnitine L-tartrate) taken as a split dose twice a day for 12 weeks or longer.
 - Each dose should be consumed with a carbohydrate containing meal to facilitate enhanced uptake.
- > Shorter term supplementation periods (1.4-3g L-carnitine / day over 3-9 weeks) may be considered where reduction in muscle soreness and damage incurred by heavy exercise is the goal.

Are there any concerns or considerations?

Lack of clarity over benefits of short-term supplementation.

Short term supplementation studies which have been undertaken on athletes and active individuals have shown no consistent responses to exercise performance or metabolism. This is due to a wide variance in supplementation duration (single dose pre-exercise through to 4 weeks daily supplementation), training status of participants, the implementation of dietary or exercise controls before testing, and the actual exercise test used/ outcome measured.

Long term supplementation requires each dose to be co-ingested with a significant amount of carbohydrate.

Very few studies have shown an uptake of supplemental carnitine into muscle, but the limited evidence suggests a large dose of carbohydrate (80g with each dose) is required over at least 12 weeks in order to achieve this. There has been no research on whether this dose of carbohydrate could be altered according to body weight or if this could be adjusted according to co-ingestion with other macronutrients, possibly enabling guidance to be adjusted to merely encourage ingestion at main meals. The additional carbohydrate, and the requirement to specifically be timed with the carnitine supplement twice daily, is unlikely to align with the caloric needs and nutrient timing that is optimal for each athlete, during each phase of training, over the period of supplementation.

Very few studies have been undertaken on elite athletes.

As such, the applicability of the research to elite athletes is uncertain.

L-carnitine may increase fasting plasma trimethylamine-N-oxide (TMAO) levels.

Increased TMAO has been linked to atherogenesis and a higher risk of cardiovascular events.⁵

L-carnitine consumption may cause mild gastrointestinal symptoms.

- > Some reports of nausea, vomiting, stomach cramps and diarrhoea have been reported during supplementation. Akin to guidance for other supplements that can result in intestinal symptoms, co-ingestion with meals may be advisable.
- > Consuming more than 3g/day may result in a 'fishy' body odour.

Where can I find more information?

Supplement safety information and batch tested product list

www.sportintegrity.gov.au/what-we-do/anti-doping/supplements-sport

References

1. Wall, B.T., Stephens, F.B., Constantin-Teodosiu, D., Marimuthu, K., Macdonald, I.A., Greenhaff, P.L. (2011). Chronic oral ingestion of L-carnitine and carbohydrate increases muscle carnitine content and alters muscle fuel metabolism during exercise in humans. *J Physiol*, 589, 963-973.
2. Shannon, C.E., Ghasemi, R., Greenhaff, P.L., Stephens, F.B. (2018). Increasing skeletal muscle carnitine availability does not alter the adaptations to high intensity interval training. *Scan J Med Sci Sports*, 28, 107-115.
3. Novakova, K., Kummer, O., Bouitbir, J., Stoffel, S.D., Hoerler-Koerner, U., Bodmer, M., et al. (2016). Effects of L-carnitine supplementation on the body carnitine pool, skeletal muscle energy metabolism and physical performance in male vegetarians. *Eur J Nutr* 55, 207-217.
4. Stephens, F.B., Wall, B.T., Marimuthu, K., Shannon, C.E., Constantin-Teodosiu, D., Macdonald, I.A., Greenhaff, P.L. (2013). Skeletal muscle carnitine loading increases energy expenditure, modulates fuel metabolism gene networks and prevents body fat accumulation in humans. *J Physiol*, 591, 4655-4666.
5. Sawicka, A.K., Renzi, G., Olek, R.A. (2020). The bright and dark sides of L-carnitine supplementation: a systematic review. *JISSN*, 17, 49.
6. Koozehchian, M.S., Daneshfar, A., Fallah, E., Agah-Alinejad, H., Samadi, M., Kaviani, M. et al. (2018). Effects of nine weeks L-carnitine supplementation on exercise performance, anaerobic power and exercise-induced oxidative stress in resistance-trained males. *J Exerc Nutr Biochem*, 22, 7-19.



The Australian Institute of Sport (AIS) Supplement Framework is an initiative of the Australian High Performance Sport System. The AIS acknowledges the support of members of the National Institute Network (NIN) and National Sporting Organisations (NSO) and their staff in delivering content expertise. This information is intended to help athletes, coaches and scientists make evidence-based decisions about the use of supplements and sports foods. Before engaging in supplement use, we recommend that each individual refer to the specific supplement policies of their sporting organisation, sports institute or parent body, and seek appropriate professional advice from an accredited sports dietitian (www.sportsdietitians.com.au).

Athletes should be aware that the use of supplements may have doping implications. Athletes are reminded that they are responsible for all substances that enter their body under the 'strict liability' rules of the World Anti-Doping Code. Some supplements are riskier than others. The Sport Integrity Australia (SIA) app is a useful resource to help mitigate the risk of inadvertent doping by helping to identify supplements that have been batch-tested. The SIA App provides a list of more than 11,000 batch-tested products. We recommend that all athletes consult the educational resources of SIA regarding the risks associated with supplements and sports foods. While batch-tested products have the lowest risk of a product containing prohibited substances, they cannot offer you a guarantee that they are not contaminated (www.sportintegrity.gov.au/what-we-do/supplements-sport).

© Australian Institute of Sport
Last updated March 2021

